HOSPITAL INFECTIOUS WASTE DISPOSAL SYSTEM DESIGN

by

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CHAPTER 1: INTRODUCTION AND METHODOLOGY

INTRODUCTION

Safe and effective hospital infectious waste disposal is accomplished by utilizing a well designed waste disposal system. A hospital waste disposal system addresses the control of waste flow from generation point to ultimate disposal. Infectious wastes require specialized treatment due to potentially hazardous/infectious agents. This document examines and outlines necessary hospital infectious waste system components. Systematically observing and controlling hospital infectious waste through collection, segregation, containment, transportation, storage and treatment allows the hospital engineer to properly design a safe, efficient infectious waste control operation.

Problem Statement: An efficient, effective and safe hospital infectious waste disposal system is necessary to meet applicable government and health care regulations, and meet the expectations of health care staff, patients, visitors and the surrounding community of having a clean, healthy, hospital environment. The waste disposal system must monitor and control hospital infectious waste from generation to disposal.

Project Goal: The paper's goal is establishing hospital infectious waste disposal system criteria. The paper deals with infectious waste generated through patient care and related treatments. The continuity and interrelationship of disposal system components are considered as the waste control system is examined and structured. The document's composition parallels the treatment methods necessary to properly dispose hospital infectious waste.

Chapter 2 studies hospital infectious waste generation. The chapter presents infectious waste definitions and looks at applicable health care organization and government infectious waste regulations and standards. Infectious waste composition is examined to demonstrate the wide variety and make-up of hospital infectious wastes. Hospital waste production and disposal costs are considered to illustrate the infectious waste disposal problem's size and importance. Chapter 2 closes with a discussion of the relative harmfulness of hospital wastes as compared to general municipal wastes.

Chapter 3 examines handling hospital infectious waste. This chapter looks at the initial waste collection, the need for waste segregation, and proper waste containment. Transporting and storing wastes are then studied to complete the waste handling cycle.

Applicable regulations are considered to help structure a waste handling system which provides safety for hospital personnel, patients, and guests, while still accomplishing the goal of removing patient waste as efficiently and effectively as possible. Specific containment materials and employee training subjects are discussed to provide a more thorough understanding of the waste handling process.

Chapter 4 provides information regarding the two most popular health care infectious waste treatment alternatives. Hospital wastes can be decontaminated by either steam sterilization (autoclaving) or high temperature incineration. Materials suited to these treatments are identified and the decontamination processes are studied. Incineration processes are discussed in greater detail because this alternative can be applied to a wider range of potentially infectious hospital wastes and is generally accepted as the preferred treatment method.

Chapter 5 contains conclusions and remarks resulting from this research. A hospital waste disposal system structure is constructed emphasizing system safety and effectiveness while still achieving the desired waste control function.

METHODOLOGY

Materials used to prepare this document were obtained from four major sources. The Kansas State Libraries, KSU Interlibrary loan, Linda Hall Library, and the Archie R. Dykes Library of the Health Sciences were primary information sources. An on-line computer search generated many initial sources. Many materials read and studied were not directly applicable to this topic but did provide general background information.

CHAPTER 2: IDENTIFYING AND REGULATING HOSPITAL INFECTIOUS WASTE

INTRODUCTION

The removal and treatment of hospital infectious waste provides many challenges for engineers, clinicians and other hospital personnel. Approximately 25% - 30% of hospitalized patients have infections and can contribute to infectious waste production.[22] This chapter looks at defining and identifying hospital wastes. The amount and composition of hospital infectious waste is studied in the context of past and presently existing federal, state and local regulations. The author recognizes the presence of several pending legislative actions on all three government levels. Hospitals themselves are also moving toward developing more uniform and efficient waste management systems. Infectious waste disposal costs are considered to demonstrate the importance and complexity of safe infectious waste management. The question is raised as to whether hospital wastes are potentially more hazardous than common municipal wastes.

DISCUSSION

Effective and safe hospital infectious waste disposal is contingent on an accurate identification of potentially hazardous substances. Attempts have been made to define and characterize hospital waste which should be considered infectious and require special treatment before disposal. Proper and efficient infectious waste disposal is an important part of protecting a health care organization's patients, staff, guests, and neighboring community from exposure to potentially infectious agents.

Regulatory agencies have attempted over the last several years to define and structure infectious waste standards. The 1976 Resource Conservation and Recovery Act (RCRA) (42 U.S.C. 6903(5)) defines hazardous waste as:

> "a solid waste, or combination of solid wastes, which because of its quantity, concentration, or physical, chemical, or infectious characteristics" may a.) cause or significantly contribute to an increase in mortality or an increase in serious, irreversible, or incapacitating reversible, illness; or b.) pose a substantial present or potential hazard to human health or the environment when improperly treated, stored, transported, or disposed of, or otherwise managed."[59]

The RCRA was intended as a tool allowing the U.S. Environmental Protection Agency (EPA) to control and

offer guidance on potentially infectious waste identification and treatment. The EPA and U.S. Congress hazardous waste definition in the 1982 EPA Draft Manual for Infectious Waste Management (SW-957) was very similar to the earlier RCRA definition:

> "a solid waste or combination of solid wastes, which because of its quantity, concentration, physical, chemical or infectious characteristics, may cause or significantly contribute to an increase in mortality or an increase in serious irreversible incapacitation or potential hazard to human health or the environment when improperly treated, stored, transported or disposed of, or otherwise managed."[20]

The Draft Manual was only considered as a recommendation or set of guidelines for identifying, segregating, transporting and disposing infectious hospital waste. The manual guidelines were not a legal requirement, just proper waste management suggestions.[24,58] The EPA did recommend institutions adopt a "cradle-to-grave" philosophy of regulating hazardous wastes from the generation point, through storage and transport, to ultimate disposal by an extensive reporting and record keeping system.[20] Guideline interpretation varied from one health care facility to the next with a resulting lack of overall consistency.

When the EPA published these guidelines, there was speculation the Centers for Disease Control (CDC) would also provide some infectious waste management guidance.

The CDC chose instead to maintain the brief waste disposal statement previously published by the CDC and not initiate any new guidelines or recommendations. The major differences between the existing CDC statement and the new EPA guidelines regarded recommended incineration and steam sterilization treatment alternatives for particular wastes (see Table 1.0. Appendix A).[62]

The Joint Commission on Accreditation of Hospitals (JCAH) published some hospital hazardous waste management standards in 1985. JCAH Standard VI obligates each accredited hospital to manage all hazardous materials and wastes comprehensively. The standard assigns hazardous waste management responsibility to the hospital's safety committee. Written policies and procedures, developed and enforced on a hospital-wide basis, are examined as part of the annual JCAH quality assurance review. JCAH waste management standards are less stringent than regulating government agencies. JCAH does require compliance with all federal, state, and local government guidelines for proper accreditation.[28] (See Table 2.0. Appendix A for JCAH Standard VI.)

The JCAH then published a monograph "Managing Hazardous Wastes and Materials" in 1986. Here the JCAH set down health care facility waste management guidelines.[47] A constantly recurring problem for all agencies attempting to define and control hospital

infectious waste treatment were the various defining parameters used by the different organizations. No clear responsibility or jurisdiction boundaries had been determined. Several interested government and health care organizations identified different wastes to be considered infectious, and suggested conflicting treatment alternatives. The CDC, JCAH, and the U.S. EPA all agreed that microbiological, blood (and blood products), isolation, pathological, and sharps (needles, broken scalpels, etc.) waste materials were to be considered infectious (See Table 1.0. Appendix B for examples of these wastes.).[64] The EPA further defined those wastes from aseptic surgery, dialysis, and laboratory as being infectious.[64] Infectious waste composition receives further attention in this chapter.

Due to these national organizations having differing opinions on what wastes to consider infectious, several state and local governing bodies initiated regulations and formulated waste defining parameters. These state and local definitions vary widely and are often vague and ambiguous.[18] An example definition of hazardous infectious hospital waste is given by the Illinois Pollution Control Board as "waste contaminated with an infectious agent that has the potential of inducing an infection and has not been rendered innocuous

by sterilization or incineration."[35] Infectious waste is sometimes more specifically defined at state and local levels - there is just a lack of overall consistency, leading to confusion, mishandling and incorrect treatment of infectious wastes. Infectious waste, also commonly called "contaminated," "biohazardous," "biological," "biomedical," "pathogenic," and "red bag" waste can be loosely defined as any waste material that is a potential health hazard because of "infectious characteristics."[18]

The most recent and popularly recognized infectious waste definition was published in Centers for Disease Control guidelines in August 1987. The new CDC guidelines recommend all waste coming in contact with a patient's body fluid be considered infectious.[14] The CDC guidelines use four infectious waste categories: contaminated needles, cultures and stocks of infectious agents, blood and blood products, and pathological wastes.[68] This definition change dramatically increases the amount of hospital waste previously considered infectious. Previous guidelines had considered only 3% or up to 11% of total solid hospital waste as infectious depending on a facility's infectious waste definition and CDC, EPA and JCAH guideline interpretations.[12,18,62] Previously, 10% of this waste was considered infectious; now between 30% and 60% of a

medical facility's total waste load can be considered infectious.[9]

Some 20 - 25 states had a required infectious waste definition by 1988.[9,29] Other states have varying degrees of legislation and regulation dealing with infectious waste management. (See Table 3.0. Appendix A for state regulation detail.)

Waste Composition

Further hospital infectious waste discussion is taken in the following context. Solid wastes include materials - in liquid, semisolid or contained gaseous states, as well as solids - which are no longer fit for original intended uses and must be either disposed or treated before reuse.[67] Medical waste includes packaging (bandage and catheter wrappers), containers (intravenous bags, empty vials), disposable items (tongue depressors, thermometer covers), and infectious waste.[56]

Infectious wastes can include cultures of infectious agents, blood and blood products, body parts and tissue samples, other laboratory wastes, needles or syringes, wound dressings, contaminated disposable items, surgical drapes and human tissue from surgery, bacteriological cultures, urine, laboratory blood and fecal samples,

medical experiment animal remains, and any object or substance that may have become contaminated during patient care. Other miscellaneous infected material might be gauze dressings, bandages, sputum cups, plaster casts, tissues wet with nose or throat secretions, hospital ward wound drainage, and waste pharmaceuticals.[2,19,22,48,52,67,71,72] Pathological waste is not necessarily infected or contaminated and esthetics may be the sole basis for the disposal method chosen unless local regulations supersede the desired hospital policy.[52]

Waste Generation

The variety and number of treatments practiced and a hospital's size directly affects the quantity and composition of the infectious waste generated. Hospital waste production estimates vary widely with 10 - 15 pounds per bed per day for hospitals with fewer than 400 beds and 15 - 20 pounds per bed per day for larger hospitals being generally accepted.[9,17,48,62,67] Two studies have looked at hospital waste composition in great detail. The first was carried out in North Carolina and the second was completed by the Ontario Hospital Association. The two studies had remarkably similar results, lending credence to the individual findings.

A 1980 study of North Carolina hospitals by Rutala identified the hospital solid waste disposal practices used (results published 1983 [62]). Questionnaire responses were obtained from 120 of the 150 hospitals surveyed. The findings were very detailed and made a very thorough examination of what constitutes hospital infectious waste and how the waste was being handled. The study also looked at how well differing regulations were being followed in waste disposal practices. The questionnaire included questions on hospital solid waste collection, storage, processing, transporting and disposal.

Rutala's study found North Carolina hospitals generate an average 13 pounds of solid waste per patient per day. Infectious wastes comprise 5% - 11% of the total hospital waste.[62] Most of the hospitals (greater than 66%) considered in the study considered blood, isolation, laboratory (including microbiology), pathology, and autopsy waste as infectious, while other solid waste sources were generally considered non-infectious.

Fifty North Carolina hospitals generated an average 9.95 pounds of solid waste per bed per day which was equivalent to 13.05 pounds of solid waste per patient per day. Forty-two of the responding hospitals reported

infectious waste comprising 10.95% of the total hospital waste.[62] (See Table 2.0. Appendix B for results.)

An Ontario Hospital Association (OHA) survey suggested a typical 250 bed hospital generated an average 6.0 kilograms (13.2 pounds) per bed per day of solid waste. Infectious wastes were thought to be ten percent of the total solid wastes generated.[51] Other OHA studies undertaken produced conflicting results regarding the amount of infectious wastes generated. Producing 1.0 kilogram (2.2 pounds) per intensive care unit (ICU) bed per day of infectious wastes was accepted by the Ministry of the Environment for strategy purposes.[51] This means approximately 17% of the solid waste generated was considered potentially infectious. This waste is presumed to need incineration or sterilization before disposal.

The American Hospital Association (AHA) estimates a single hospital produces approximately 25 pounds of general waste per patient each day. Using the CDC's infectious waste definition a typical hospital's infectious waste would range from 8% - 12% of the total amount generated - or two to three pounds per patient each day, according to James McLarney, AHA's Director of Facilities Management.[69]

Other smaller studies have produced varying results. There appears to be agreement on the basic amount of hospital solid waste produced. The quantities of a

hospital's wastes considered infectious are subject to biases caused by differing CDC guideline, and state and local regulation interpretation. These smaller studies demonstrate the magnitude of the disposal problem of potentially infectious hospital wastes. Assuming an average hospital produces 1.5 pounds of infectious waste per bed per day amounts to 1.4 million pounds of infectious waste generated per day nationwide. This is 491 million pounds per year, using figures based on 1985 American Hospital Association (AHA) estimates of 69% occupancy of the 1.3 million licensed hospital beds.[54] A 200-bed community hospital annually produced over one million pounds of solid waste, approximately 3,000 pounds each day.[67]

These findings are included to provide a more practical visualization of the waste management problem. The problem continues to grow as increasing numbers of patients are treated in both on-site and off-site health care facilities. The AHA reports the infectious waste volume generated outside a hospital is rising as care moves to out-patient facilities.[29] This trend will require legislation and regulation for small and dispersed waste producers.

Small quantity waste generators are currently required to:

1. determine whether their wastes are hazardous,
2. obtain an EPA identification number,
3. store hazardous waste on-site for no more than 180-270 days in compliance with specifically modified storage standards,
4. offer wastes only to transporter and facilities with an EPA identification number,
5. comply with applicable Department of Transportation requirements for shipping wastes off-site,
6. use a multi-part "round trip" Uniform Hazardous Waste Manifest to accompany waste to the final destination,
7. maintain manifest copies for three years.[26,38]

The compliance date for these requirements was September 22, 1986 for small quantity generators, off-site facilities managing waste from 100 - 1,000 kilograms per month generators, and off-site facilities managing waste from both large and small quantity generators.[6,38] A small quantity generator is defined as a facility generating 100 - 1,000 kilograms of waste per month. Previous EPA guidelines had not covered these small quantity producers. Future waste disposal regulations will need to consider these smaller volume generators.

Potential quantities of waste generated can be predicted using a model developed by Steencken et.al.[65] Multiple regression analysis indicated a positive correlation between infectious waste generation and both the number of patient admissions and total surgical procedures. The study predicts the amount of infectious waste generated is found using:

$$I = 0.00279P + 0.03763A - 14.5365$$

where: I = tons of infectious waste/month
P = total surgical procedures/month
A = total admissions/month.[65]

Hospital wastes are highly variable in content; about 85% of the total hospital waste stream can be categorized as general refuse, which is non-hazardous. Hospital wastes usually contain about 20% plastics, with levels as high as 30% to 70% being reported.[16,19] In comparison, municipal solid waste contains about 3% - 7% plastics.[16,19]

Waste Disposal Costs

Infectious waste disposal costs range from 40 to 95 cents per pound, depending on the treatment and disposal techniques used and required by specific state regulations. Nationwide this amounts to $545,000 to $1.3 million per day or as much as $466 million per year.[54] Larger hospitals can receive better deals for infectious waste hauling. Costs run as high as $1.00 per pound in the Northeast and 45 to 90 cents per pound in other states (see Table 1.0. Appendix C.)[12]. Major waste system costs were labor and off-site hauling, 56% and 17% of the total cost respectively.[2]

There are definitely significant costs involved in an infectious waste disposal system. Specific examples

illustrate the expense a health care facility incurs when practicing safe waste disposal.

For a typical 200-bed hospital, infectious waste disposal costs were $120 to $285 per day or as much as $104,000 per year.[54] Non-infectious waste removal costs for The Graduate Hospital in Philadelphia, Pennsylvania increased by 55% due to an area landfill closing. New infectious waste containment policies resulted in a staggering 580% cost increase. Infectious waste removal expenditures increased again in early 1986, a result of new procedures and a hauling firm change, to more than double the previous amount. 1986 hospital campus waste removal costs were estimated at $110,000 for non-infectious waste and $499,000 for infectious waste.[65] Staten Island Hospital, a 462-bed facility, currently pays approximately $300,000 annually for waste handling. Infectious waste disposal using a manifest system (already in place) accounts for about half the cost, says Mike Freeland, Director of Environmental Services.[8]

Are Hospital Wastes Harmful?

The question is raised as to whether hospital wastes are harmful to the degree requiring extensive regulation and control. According to the CDC and various experts "there is no epidemiological evidence to suggest that

most hospital waste is any more infective than residential waste. Moreover, there is no epidemiological evidence that hospital waste disposal practices have caused disease in the community."[14]

The EPA's position is that infectious waste regulations are not justified because there is not sufficient evidence these wastes harm human health or the environment.[23] An "infectious" waste contains pathogens of sufficient virulence and quantity that a susceptible host's exposure could result in an infectious disease.[20,23]

There is no microbiological evidence suggesting hospital waste is more infective than residential waste.[39] With the exception of sharps, there is only one instance of waste associated with in-hospital infection transmission - this occurred in 1974 and involved a hydropulping waste system no longer used in the U.S.[30] Although much of the public's concern regarding infectious wastes is incited by a fear of AIDS, no environmentally mediated mode of human immunodeficiency virus transmission has been documented.[14]

Hospitals and health care facilities cannot ignore the potentially damaging effects an improper infectious waste disposal incident could inflict. Hospitals are

expected to provide and maintain a clean, healthy and safe environment. Regardless of whether or not hospital wastes are potentially more infectious than municipal wastes, great care needs to be taken in waste disposal. Eighty percent of U.S. hospitals comply with present CDC infectious waste guidelines.[62] Current applicable standards, when correctly implemented, appear to provide the measure of public and facility safety the profession and the community at large desire.

SUMMARY

This chapter presented past and present hospital hazardous/infectious waste definitions. The regulatory agencies involved were studied to determine current waste management guidelines and applicable standards. The currently accepted guideline published by the Centers for Disease Control defines infectious waste as all waste coming in contact with a patient's body fluid.

Hospital waste production is estimated at 10 - 15 pounds per bed per day with at least 10% of the hospital waste generated considered infectious. Hospitals producing 1.5 pounds of infectious waste per bed per day generate 1.4 million pounds of infectious waste per day nationwide. This amounts to 491 million pounds per year. Infectious waste disposal costs are estimated at as much as $466 million per year.

The argument can be made that specially treating infectious wastes is unnecessary. No epidemiological or microbiological evidence exists suggesting hospital wastes are more infective than residential wastes. Hospitals must recognize that their societal position as health providers requires the proper implementation of waste management practices.

CHAPTER 3: HANDLING HOSPITAL INFECTIOUS WASTE

INTRODUCTION

A safe, efficient and effective hospital waste management system is dependent on proper waste collection, segregation, containment, transportation, and storage. Federal, state, and local regulations and guidelines provide a basic framework from which a health care institution must construct policies and procedures to properly handle infectious waste. This chapter looks at the design and structure of the waste handling system necessary to adequately address these needs.

All segments of any hospital waste handling system must be strongly integrated with other system components. Waste collection and segregation at the generation site is followed by containment, and then subsequent transportation or storage. Strict adherence to prescribed collection and segregation policies, correct waste containment, proper equipment, and detailed employee training, all combine to present wastes suitable for disposal, in a manner providing the utmost safety and concern for the health care facility's patients, staff, visitors, and neighboring environment.

DISCUSSION

The Environmental Protection Agency's (EPA's) "cradle-to-grave" approach to infectious waste management regulates wastes from the generation point, through storage and transport, to ultimate disposal by an extensive reporting and record keeping system.[23] The EPA guidelines are intended to assist health care institutions in the design and practice of safe, effective waste management programs. Proper infectious waste identification allows for specialized handling and treatment of these potentially hazardous substances by health care personnel. The safety of health care patients, staff, visitors, and the surrounding environment can potentially be compromised due to poor design and implementation of infectious waste disposal systems. Infectious waste collection, segregation, containment, transport and storage is therefore a very important segment of the hospital's infection control program.

Regulations governing hazardous/infectious waste handling, transportation, and disposal have become increasingly stringent and encompassing. Hospital infectious wastes are considered a subset of hospital hazardous waste. All facilities need a hazardous/infectious waste program to provide direction

and information on proper waste identification, handling and treatment. Hazardous waste programs should include the following:

1. written materials describing systematic policies and procedures for dealing with specific problems, and
2. a regular and ongoing policy and procedure effectiveness review.[47]

Policies, procedures, and a written inventory and tracking program for hazardous materials and wastes must be prepared for local and federal regulation compliance. A complete infectious waste management program includes obtaining and keeping necessary manifests and permits, inspection and survey reports, an emergency response plan, and a training program for all hazardous material users and handlers.[7]

Waste Collection

Waste collection at the generation point is typically a function of nurses, housekeeping, or other infection control staff. Collections should not create disturbances, yet be frequent enough to minimize odors and health or fire hazards.[63] Rutala (1983) found 96% of the responding North Carolina hospital's staff collected solid waste at least once a day. Sixty-five percent of the hospitals collected waste two or more times per day.[62] Waste collection is time consuming, potentially hazardous, and a necessary part of a

successful waste management program. A health care institution should tailor waste collection patterns and procedures to best facilitate effective and safe collection and subsequent waste segregation, containment and transportation. Waste collection schedules and routes should minimize potential hospital environment waste exposures.[5]

Waste Segregation

Infectious waste is separated from general waste to assure the waste presumed to contain potentially hazardous levels of microorganisms receives proper handling and treatment.[61] Waste segregation should be accomplished at the generating site (patient room, laboratory, dialysis, surgery, or any other waste generating site) by personnel familiar with the facility's infectious waste policy and the wastes to be segregated.[5,23,37,47,50,61,64] Generation point segregation reduces the waste handling and sorting required and can reduce the waste volume requiring specialized treatment before sewer or landfill disposal.[16,37,50,61,64] Waste volume reduction is an important step in an effective waste management process.

Many institution's infectious waste segregation policies are becoming overly conservative. Consequently, significant quantities of general, non-infectious waste

are being intermixed with red bag waste. Such practices obviously increase "apparent" infectious waste quantity levels.[18] The conservatism and concern of many hospital safety and infection control personnel clearly reflects the importance and significance being placed on a safe and effective waste segregation and disposal policy. The potential exists for accidents and employee oversights which could endanger the hospital or neighboring community. Some people believe an entire waste load should be considered infectious, and treated as such, when any infectious waste is intermixed or found in the load.[61] Proper segregation is thus an effective disposal strategy prerequisite.[16]

The first line of defense against accidental infectious waste exposure is a well designed, implemented and enforced segregation policy. Key elements of a waste segregation policy are:

1. a minimum number of decision points,
2. an easily understood and properly instituted segregation code,
3. readily visible, clear and concise instructions to act as reminders to staff (displayed at collection points),
4. adequate staff training, and
5. a regular monitoring system ensuring the policy is effective when practiced.[41]

These ideas provide the framework for designing and instituting a proper infectious waste segregation, containment, storage and transportation system.

The initial challenge is determining which wastes are infective or non-infective. Individual facilities produce waste loads of varying composition.[13] The segregation code is therefore based on restrictive criteria aimed at minimizing personnel exposure and mistakes and maximizing personnel effectiveness and efficiency. Actually, hospital wastes need to be segregated twice: the first division separates potentially infectious from non-infectious waste; the waste is then segregated according to the most effective treatment method. Some wastes are more appropriately treated by steam sterilization than incineration and vice versa.[64]

A facility's segregation criteria are determined by physical and chemical properties of waste components. Emphasis should be placed on segregating "risk" waste - pathological and infectious - from other waste and using appropriate packaging and labels.[50] Waste materials fall into two basic categories. The first is waste which is anatomical or of a high water content (ex. body tissues, parts, body fluids). The high moisture content and high density make steam sterilization a time inefficient process. These wastes can be incinerated.[64] The second category includes articles contaminated by persons or materials potentially harboring pathogenic microorganisms. Infectious wastes

most suited for steam sterilization are those having a relatively low density and low to moderate water content. These wastes may include disposable garments, sheets, gloves, syringes, laboratory plastic-ware, dialysis tubing, and surgical sponges.[37,64]

Waste Containment

The primary objective of infectious waste containment is minimizing or eliminating personal infectious waste material exposure.[64] Previously, much hospital waste considered potentially infectious was double-bagged to provide improved containment and worker protection. Double-bagging isolation room waste was found to be unnecessary from an infection control perspective.[61] Operating a successful waste management program requires correct waste containment material usage.

Areas generating potentially infectious waste need the proper waste containment materials readily accessible.[37] Waste containers need to be sturdy, clean, leakproof and clearly marked.[47] The containers must be sized so the bag liners will be transportation system compatible in size and durability. The liners should be of more than one material, several standard colors, and from several competitive sources. Liners

used to hold infectious waste must be 3-millimeters thick and should be a stock size.[37,43] Color-coding high-risk waste bags and containers with appropriate emblem-coded tags could reduce accidental exposure and ensure proper disposal segregation. Rutala found 91% of North Carolina hospitals segregated infectious from non-infectious waste, and 93% of these hospitals did so by labeled or color-coded bags.[62] National color-coding and emblem-coding standardization could be advantageous in that establishing a uniform and consistent system would reduce confusion and the potential for waste mismanagement.[50]

Rutala found 98% of the North Carolina hospitals used plastic bags as wastebasket liners (the initial containment). Wastebasket containers used were plastic (41%), metal (17%), and plastic and metal (40%). The wastebaskets were generally leakproof (88%).[61] Most health care facilities would report similar initial waste generation point containment.

Steel wastebaskets are preferred over aluminum, magnesium or plastic wastebaskets because steel wastebaskets are more likely to contain any fire outbreak and are less likely to furnish enough fuel and toxic smoke to escalate a controllable situation.[63] Expense and cleansing effectiveness are two variables considered

when selecting hospital waste receptacles and reflect the high plastic container use Rutala reported.

Health care establishments should segregate and concentrate waste to simplify waste management.[50] Segregated wastes should be put into single-use, moisture proof bags hung in special holders or bags used as plastic or metal container liners. The bags should be strong enough to resist internal and external mechanical damage and should only be filled to a level allowing easy and tight bag closing.[50] Overfilled bags may split or open, allowing unintended waste exposure.[41]

The Centers for Disease Control (CDC) has recommended placing intact syringes and needles into impervious, rigid, puncture-proof containers for the last ten years.[49] Infectious waste containers should be sealed before transport and be compatible with the intended treatment or disposal method.[50]

Complete incineration requires a combustible waste container.[64] Combustible containers decrease infection risk (are never reused), reduce necessary worker handling of potentially infectious waste when storing and loading the wastes in the incinerator, and contribute incinerator combustion process fuel.

Steam sterilization under pressure (also called autoclaving) of hospital wastes is a popular disinfecting technique. Containment material is very important to an

efficient and effective steam sterilizing system. Effectively sterilizing a waste load requires high temperature steam to totally penetrate the waste load and maintain the extreme waste/steam temperature for a sufficient time period. High-density polyethylene or polypropylene, thermoplastic materials are steam impermeable. Air evacuation and steam sterilization of the bag's contents are inhibited. This slows the steam penetration process into the deep recesses of the load and reduces the steam temperature through dilution with the cooler entrapped air. These bags severely reduce the efficiency of steam as a sterilizing agent thus compromising decontamination effectiveness and lengthening the sterilizing time necessary.[64]

Low-density polyethylene (LDPE) waste containment bags are recommended.[37,62,64] The LDPE bags melt at temperatures above 180 ^{o}F and thus allows waste load air evacuation and thorough steam penetration. Employing meltable low-density polyethylene bags as primary and secondary containment has been shown to increase steam sterilization process efficiency.[64] The autoclaving bag should have an indicator which darkens on exposure to heat and steam (or some similar measure demonstrating the bag has been processed before being placed in the nonhazardous waste collection).[47]

Additional U.S. EPA health care infectious waste containment recommendations include:

1. using distinctive, clearly marked containers or plastic bags for infectious waste,
2. using the biological hazard symbol on infectious waste containers as appropriate,
3. selecting appropriate waste packaging material (plastic bags for many solid and semi-solid infectious waste, puncture - resistant containers for sharps, and bottles, flasks or tanks for liquids),
4. using packaging material which maintains integrity during storage and transport,
5. using plastic bags which are impervious, tear resistant, and distinctive in color and markings,
6. closing each bag by folding or tying as appropriate for the treatment or transport, and
7. no pre-treatment infectious waste compaction.[23]

Once the waste is properly contained in bags or boxes, two essential factors necessary for communicable disease transmission are not present - mode of transmission and portal of entry. Unless a waste handler is negligent or container integrity is violated, there is neither an infectious agent transfer mechanism from the waste to a susceptible host (exposure) nor a portal of entry by which an infectious agent can enter a susceptible host.[57,62]

Waste Transportation

Hospital waste transportation relies on using transfer carts. The recommended procedure is to collect and segregate waste at the generation point and transport using closed transfer carts to the treatment area.[40]

Rutala (1983) found greater than 67% of North Carolina hospital transfer carts to be plastic, rectangular-shaped units with casters.[62] Anodized aluminum or stainless steel carts are also common.[43] Transfer carts should have a singular purpose, be disinfected regularly, and should not be placed in passenger elevators.[43,50,62]

This general purpose material handling system can effectively and safely move a great part of the total waste load at relatively small capital cost.[43] Safe waste transportation within a hospital facility should use three different cart (or other closed container) fleets designed for each designated waste treatment destination: steam sterilization, incineration, or general waste disposal.[5] Respective container characteristics are identified so the waste collected can be segregated, transported and stored until disposal in the safest and cleanest possible manner. The specific container types are necessary to improve infection control, reduce waste rehandling and container damage, and ensure proper cleansing.

Safe waste transportation depends on properly designed and operated transfer carts. Properly designed carts protect hospital personnel, patients, and guests from unnecessary waste exposure. These transfer carts also protect the integrity of waste containment bags and boxes. Some desirable cart design features include:

1. narrow enough to pass easily through doorways, pass other vehicles in corridors, easily access rooms, elevators, or cart lifts,
2. low enough so attendants can see over them,
3. completely enclosed with doors on two sides and the top,
4. a self-draining bottom (or leak-proof depending on intended use),
5. constructed of materials suitable for regular automatic washing (mechanically strong, reasonably light and corrosion resistant - anodized aluminum or stainless steel),
6. have two swivel casters and two fixed-position wheels,
7. resilient tires coordinated with floor surfaces to minimize floor marking and damage,
8. wheel bearings capable of enduring repeated washings,
9. resilient bumpers on all sides coordinated with corridor and elevator rub-rail heights,
10. doughnut bumpers on both ends, and
11. all latches and fasteners stainless steel.[43,62]

The hospital personnel actively collecting, segregating and transporting wastes experience a significant amount of contact with potentially infectious substances. Waste "transporters" have the additional responsibility of moving potentially hazardous cargoes in what is expected to be a clean, safe, healthy atmosphere. Additional cart handler training guidelines should include:

1. load material onto carts in an orderly manner,
2. keep to the right, go slow near stairways, corridor intersections, elevators and on ramps,
3. look ahead,
4. keep hands away from cart's edge when pushing to avoid pinching,
5. avoid leaving the cart, equipment, or supplies where someone might trip over or bump into them,
6. keep cleaning materials where they belong so the cart itself does not need housekeeping,

7. report any need for cart repair, and
8. pull the cart through swinging doors.[63]

The 1986 U.S. EPA Guide for Infectious Waste Management addresses many of the concerns just discussed in the following waste transportation recommendations:

1. avoid mechanical loading devices which may rupture packaged wastes,
2. frequently disinfect carts used to transport a facility's wastes,
3. place all infectious waste into rigid or semi-rigid containers before off-site transportation, and
4. transport infectious waste in closed, leak-proof trucks or dumpsters.[23]

Waste Storage

Infectious and pathological waste may be stored in sealed bags for short time periods but waste treatment is desirable immediately following collection.[23,40,47] Waste storage is limited to areas identified by biohazard signs. Only authorized housekeeping and engineering personnel should have access to these waste storage areas.[5,23]

Storage facilities should be large enough to accommodate 24 hours of waste generation.[7,41,43] Waste material removal from the transportation system should be coordinated with incinerator charging requirements. The material handling system should transfer the waste directly to the incinerator's charging device, thereby limiting additional and unnecessary waste exposure.[43]

Recent research demonstrates current waste storage programs. There is a recognized need for leak-proof and covered storage containers, storage area housekeeping, and frequent waste removal.[7,23,41,62]

Employee Training

All health care establishment personnel, especially waste management personnel, should receive education and training regarding the potential risks of mishandling wastes.[27,50,69] Explaining and enforcing waste management guidelines can improve employee attitudes and operations.[58]

Only properly trained and oriented personnel should handle the institution's wastes.[37,57,58] Training should stress the proper segregation, containment, transportation, treatment and disposal of hazardous and infectious waste, as well as the proper attire for various working conditions. Training should cover accidental spills, proper cleanup procedures, safeguards, where responsibilities lie in cases of accidental spills, and hazardous or infectious material exposure procedures for personnel.[27,37,57,61] Additional training might include hazardous waste history, legislative history, storage and classification programs, in-house management programs, equipment handling, technologies, special

problems, resource recovery, transportation, The Resource Conservation and Recovery Act (RCRA), and other safety tips.[58]

Individuals involved in waste disposal should be careful to:

1. avoid digging into wastebaskets to empty contents (plastic liners minimize handling),
2. refrain from picking up any chemical bottles intended for disposal unless trained and assigned to this job,
3. properly handle and contain sharp objects,
4. separate pressure cans from other trash and puncture appropriately prior to incinerator disposal,
5. remove bulky combustible waste from the building as often as manpower permits, and
6. keep trash containers covered, especially in public areas.[63]

Personal protective equipment use and other safety precautions are necessary to prevent or minimize infectious substance exposure. Employee training classes should inform employees that when correct, safe procedures are followed, there is little danger from these potentially infectious agents.[36,50,58]

SUMMARY

This chapter presented hospital infectious waste handling guidelines and recommendations. Paralleling the Environmental Protection Agency's cradle-to-grave infectious waste management philosophy, this author presented a waste handling system incorporating collection, segregation, containment, transportation, and storage. Documentation and acquiring appropriate permits and manifests are part of this all encompassing program. Applicable government guidelines and regulations, research results, and a survey of present hospital waste handling practices provided this information.

Waste collection should follow some prescribed schedule minimizing personnel exposure and contributing to remaining facets of the waste handling system. Segregation should be accomplished at the generating point by personnel trained in waste segregation and subsequent containment. Containment materials should be combustible for incineration bound waste. Collect autoclavable wastes in low-density polyethylene containment bags. These bags enhance proper and efficient steam sterilization. Waste containers need proper identification markings as do transfer carts and waste storage areas. Desirable transfer cart design

features and proper cart operating practices are discussed to demonstrate acceptable hospital infectious waste transportation. Infectious wastes should only be stored for short time periods and then correctly disposed. Employee training should include proper waste collection, segregation, containment, and transportation techniques.

CHAPTER 4: HOSPITAL INFECTIOUS WASTE TREATMENT

INTRODUCTION

Safe hospital infectious waste disposal requires appropriate waste treatment. This chapter considers the two most effective infectious waste treatment methods: steam sterilization and incineration. Specific attention is given to incineration system design, the incineration process, other incineration alternatives, operating a hospital incinerator, incinerator emissions, and incinerating hospital waste advantages. Incineration processes receive emphasis because incineration adequately treats a wide variety of hospital waste products. Applicable regulations and legislation are discussed.

DISCUSSION

Health care administrators, legislators, and the public have valid concerns regarding improperly packaged, treated, or disposed hospital infectious waste. Hospital infectious and non-infectious waste requires proper disposal to ensure waste exposure or environmental contamination does not occur. Ocean and lake dumping, or simple landfill disposal are no longer environmentally acceptable disposal options. Landfill dumping and some incineration techniques have failed to meet complete infectious waste disposal requirements and are coming under intense scrutiny by government and health care regulatory bodies. Many people argue that properly operated high temperature waste incineration followed by sanitary landfill disposal of the ash, is the most reliable and preferred hospital infectious waste disposal method.[2,18,21,32,41,50,53,62,67]

A sanitary landfill buries waste a minimum two feet deep, and the landfill site is located where neither scavenging nor water pollution is possible.[4] A solid waste landfill having no groundwater and surface runoff separation can contribute to downstream habitat or groundwater contamination.[60] Locating and using a properly designed, maintained, and operated sanitary

landfill is necessary to a successful hospital waste management program.

Presently most hospital wastes are buried in class A landfills.[62] A class A landfill is considered to operate as a public non-health hazard because wastes are covered daily and no deliberate burning is done. Available and suitable landfill space is decreasing and rapidly becoming more expensive. A 1987 Environmental Protection Agency (EPA) study estimated that less than 15 years of landfill capacity remained in the continental U.S.[55] Landfill costs rise as waste haulers travel greater distances and pay increasing fees for acceptable space. The waste treatment cost prior to disposal varies considerably; costs range from $0.01 to $1.00 per pound, according to a recent Congressional Office of Technology Assessment report.[25] Costs mount as waste handling becomes increasingly specialized and more stringently regulated.

Grinding solid wastes and flushing the material into a sanitary sewage system is another common waste disposal technique.[62] The wastes discarded using this method are mainly garbage but occasionally grinders have been used for disposing direct patient care wastes.[62] Grinding and disposing infectious waste to a sanitary sewage system is not considered appropriate disposal and raises concerns regarding infectious microorganism

aerosolization during grinding and potential downstream contamination.

Waste material compaction greatly reduces waste volume and is an acceptable general waste treatment. Compaction has been found to interfere with steam sterilization and incineration waste treatment. Compacting infectious wastes can result in undesirable microorganism aerosolization.[20]

Steam Sterilization (Autoclaving)

Steam sterilizing (autoclaving) infectious waste is widely practiced because autoclaving is considered a reliable, cost-effective, and easily controlled on-location decontamination process for certain materials.[40,45] Rutala found 41% of North Carolina hospitals used steam sterilization to treat a portion of the infectious solid waste load.[62]

The autoclaving process uses high temperature saturated steam under pressure to decontaminate the waste load. Infectious wastes selected for steam sterilization are usually wastes having a low density and a low to moderate water content. Appropriate waste and proper containment materials were previously discussed in Chapter 3. Steam sterilization can effectively

decontaminate infectious material but the process does not significantly decrease waste volume.[37,64]

Effectively autoclaved waste reaches a minimum temperature of 115 ^{o}C for 20 minutes.[45] The correct holding containers and additional water can reduce sterilization time and improve process effectiveness.[45] The steam and waste temperature must be raised and maintained or waste material in a container's interior may not be completely disinfected.[40] Suitable autoclave effectiveness testing should incorporate spore strips or a variation of this method.[47]

Autoclaving a cubic yard of waste in a medium size incubator costs approximately $100. This figure is based on 1980 fuel prices and labor wages of about $6 per hour and does not include the machinery cost.[31] Autoclaves are notoriously inefficient waste sterilizers when improperly loaded and operated. Often 30% or more of the waste load is not sterilized. The attempted autoclaving simply serves to incubate contaminating microorganisms allowing faster bacteria growth.[31]

Incineration

High temperature incineration provides the safest, most cost-effective, most reliable, and cleanest disposal method for hospital infectious or biological waste.[2,21,34,41,50] High moisture and high density

infectious wastes are usually incinerated because steam sterilizing these particular wastes is time and energy inefficient.

Waste incineration is popular due to decreased material handling, weight and volume reductions, and effective pathogen control. Rutala found 77% of the responding North Carolina hospitals had on-site incinerators for burning infectious waste. Eleven percent used a contract incinerator and 12% did not incinerate any solid waste.[62] Commercial incineration prices range from $80 per cubic yard in New York City to $50 per cubic yard in Virginia and Maryland.[31]

A typical health care facility uses a dual chamber incinerator to treat infectious waste. The incineration process breaks down the material and destroys potentially harmful microorganisms. Oxygen-starved combustion in the ignition (primary) chamber is followed by an excess oxygen environment in the combustion (secondary) chamber.[46,67,71] Ash is the only residue remaining after incineration is complete.

Air emissions are an important consideration when incinerating. Purifying the discharged air of potentially harmful airborne pathogens requires secondary chamber air temperatures to reach from 1800 to 2000 ^{o}F for approximately five seconds.[53,71] The necessary

incinerator temperature and time is subject to local environmental agency regulations. These subjects receive further discussion in the remainder of this chapter.

Incineration is a complicated process requiring well-trained and qualified operating personnel and good maintenance programs to insure infectious and hazardous materials are being rendered completely harmless.[37] Standard operating procedures need to be followed. A properly designed and operated incinerating system will protect incinerator operators, appropriately handle infectious waste, and prepare the hospital waste for an environmentally safe disposal.

The Incineration Process

Infectious waste destruction is the ultimate goal of the incineration process. Incineration uses either direct or indirect heat to break chemical structures of organic compounds reducing the volume and toxicity of the remaining substances.[46] Chemically, incineration is an intensive oxidation process. Combustion or incineration basically refers to rapid organic substance oxidation.[46]

Incineration's basic objective is efficiently reducing material to an ash suitable for landfill disposal while exhausting gas products posing no environmental threat. Secondary objectives include

decontaminating wastes while minimizing energy usage and system maintenance costs.[46]

A controlled air incinerator operates in the following fashion. The waste is fed onto the primary chamber floor either manually or mechanically, and either in a batch process or intermittently. The controlled air incinerator introduces combustion air into a sealed combustion chamber using very closely controlled blowers. The air flows through the primary chamber firebed producing temperatures from 1,200 to 1,800 ^{o}F. The wastes burn in the oxygen-starved atmosphere and are destroyed through pyrolysis or destructive distillation. Wastes having low calorific values, generally because of a high water content, such as human tissue, require additional furnace heat which is usually provided from gas or oil fired burners which will maintain the high furnace temperatures necessary to complete the incineration process.[21]

The combustion products, including gaseous hydrocarbons and small amounts of particulate matter, flow into the excess-air-charged secondary chamber where the air injection permits full gas oxidation, either spontaneously or by afterburner ignition at temperatures of 1,800 to 2,200 ^{o}F.[43] Combustion at 1800 ^{o}F for more than five seconds is considered necessary to destroy

bacteria while minimizing smoke and odor emissions.[53] Most common hospital waste components burn in the gas phase rather than the solid phase. The dual chamber incinerator stack becomes an integral part of the combustion process. The three process stages minimize the emission of unburned gases and suspended particles.[31,53,65]

Continuous skilled operator supervision is essential because of the problems associated with handling and burning solid wastes.[19] The process requires dedicated equipment, effective sterilization monitoring, significant labor and is accompanied by unpleasant odors.[22] The resulting granular debris, when properly treated with a chemical decontaminant (if necessary) is safe for sanitary landfill disposal.[22]

Incineration System Design

Incineration is the preferred hospital pathological and infectious waste disposal method. Present day incinerators often consist of five components: primary combustion chamber, secondary combustion chamber, burners (one each in the primary and secondary chambers), an air supply system, and electrical controls such as a variable timer, thermoregulators, switches and wiring.[16,53]

An incinerator should be capable of burning health care waste under controlled combustion conditions,

producing a sterile residue. Effective incinerator design depends primarily on: 1. physical form of the waste, 2. total thermal input, and 3. special performance requirements.[19] Design parameters of incinerators should be related to either the most difficult material to burn or that which is most likely to create hazardous emissions.[16] The incinerator's heat input for wet pathological waste is provided by the fuel used to fire it; while the heat input to a refuse incinerator may come almost entirely from the waste.[19] Dry combustibles (paper and plastics) can be burned on a grate with cold air blown up through the load. Wet solids require hot air for effective combustion. Properly combining burning temperature and retention time ensures efficient waste combustion.[50] An incinerator which burns all wastes well is difficult to design.[19] Obtaining additional more specialized incinerators may not be feasible due to limited floor space and financial capital.

Incinerators are sized on the thermal input rate with consideration given to factors including bulk density, various waste types, and moisture content.[13] The heat release rate primarily determines the unit's size rather than the waste feed rate. The waste feed rate is determined by the amount of heat release or absorption and not on a simple pounds per hour basis.

The fuel feed rate must be controlled in order to maintain an adequate temperature.[19]

An incinerator system should have: adequate capacity, the ability to handle all waste as designed, maximum reliability, proper automatic feature incorporation to reduce operator guesswork, sufficient safety devices and alarms to assure maximum personnel and equipment protection, debris acceptable for normal landfill dumping, a wet-process decontaminator to eliminate internal cleaning and odors, an acceptable hospital environment noise level, and the capability to operate within local pollution codes at all times.[1,7,43]

Incineration Method Alternatives

A new incinerator market entry is the cyclonic incinerator, a type of excess-air incinerator. The name cyclonic refers to the internal tornado-like currents the system uses in the waste treatment process. Air inlets, located above the hearth, produce a cyclonic flow in the incinerator operated at temperatures of 2,500 to 3,500 $^{\circ}$F.[67] The extreme temperatures ensure a more complete burning of wet and dense waste material and may result in less smoke during combustion. Cyclonic incinerators are likely to produce more emissions. Manufacturers claim these emissions are effectively

trapped in a special "grit arrester compartment" which is facilitated by the cyclonic flow. The arrester compartment may eliminate the need for bag houses and scrubbers.[67]

Rotary kiln incinerators, commonly used in Europe, are excess-air burners and have the advantage of relatively simple operation. The incinerators employ moving hearths rather than grates to promote mixing between combustion air and the solid waste. Rotary kiln incinerators must use more air than dual chamber systems to ensure complete combustion.[67]

Incinerator Operation

The high combustion efficiencies of modern controlled air incinerators assure complete hazardous/infectious compound destruction and minimal trace emissions of toxic air contaminants.[19] Only about 15% of American hospitals now utilize these incinerators.[10]

Incinerator facility operation requires a high skill level because of the variety of problems associated with the handling and burning of many types of complex wastes.[16] Incomplete pathological waste destruction is primarily a result of variation in any of the five basic parameters: waste composition, waste feed rate,

combustion temperature, air and fuel feed rates, and internal flow paths.[15,60,67]

Predicting incinerator combustion rates is hard because the typical waste feed varies a great deal. Controlling the air flow to match the oxygen consumption rate is also difficult. Inadequately controlled air flow means either incomplete combustion or low operating temperatures.[16] Waste load variations reflect moisture content, material composition and density, and excess fuel additions.

Low exhaust gas oxygen levels means there is insufficient air to completely oxidize all the wastes. This results in increased carbon monoxide and hydrocarbon emissions.[16] Any single factor or a combination thereof can mean incomplete bacteria destruction and potential incinerator ash residue or stack emission microorganism contamination.[19]

Additional incinerator operation guidelines include:

1. do not dump freshly etherized waste, other chemical waste, or pressure aerosol cans into the incinerator,
2. wear a face shield, gloves and clothing buttoned at the neck and cuffs when loading the incinerator,
3. the incinerator should be the high-temperature type equipped with auxiliary fuel burners, operation controls in series, and fitted with appropriate air pollution control controls,
4. incinerator charging should only be done by designated individuals,
5. the incinerator should have other safety features such as a signal when the incinerator door is open, shutoff valves, etc., and

6. post procedures and schedules for operating, cleaning, maintenance and inspection.[15,63]

Proper incinerator use produces wastes suitable for disposal, air emissions which are not harmful, and a waste disposal process posing no health or safety threat to health care personnel.

Incineration Emissions

Hospital incinerators often produce smoke or other emissions because some materials are not burned effectively.[3,32,60] The materials an incinerator burns directly affect emission quantity and the emission control equipment needed.

The Clean Air Act's emission standards require many incinerator units to have fuel fired after-burning devices to eliminate smoke emission. Grit arrestation equipment can remove particulate matter so the exhaust gases can be discharged through the chimney into the atmosphere.[21]

Increased disposable item use has raised the quantities of plastics found in many hospital waste loads. Incinerating these wastes has given rise to new concerns regarding improper hospital waste incineration. Laboratory research on polyethylene, polypropylene and polyvinyl chloride combustion has indicated that in addition to particles and carbon monoxide, ethane,

ethylene, propane, propylene and hydrochloric acid are emitted.[11] Emission testing of incinerators burning plastic-rich waste has identified even more contaminants including furans and dioxins.[19]

Completely burned halogenated organics will usually generate hydrochloric acid (HCL) and/or chlorine acid gases depending on combustion conditions. HCL emissions can corrode metals, irritate the eyes, nose and throat and can contribute to acid rain problems.[44] Chlorine is a toxic air contaminant.[19] Excess air in the incinerator can cause lower combustion temperatures by dilution with cool gas. This inhibits HCl formation because the additional oxygen forces the reverse reaction toward greater chlorine concentration. Highest HCl concentrations occur during continuous incineration loading.[3]

Typically stack emissions consist of products of combustion (oxides of nitrogen, sulfur oxides, carbon dioxide, water, hydrogen chloride, particulates, trace metals and trace metal complexes) and products of incomplete combustion (carbon monoxide, polycyclic compounds including dioxins and dibenzofurans, chlorinated phenols, aldehydes and other incompletely oxidized organic species, and particulates).[16] Carefully controlling fuel rates and operating

incinerators at optimum combustion temperatures and secondary chamber residence times will reduce incomplete combustion products.[16]

Ensuring a hospital's incinerator complies with air quality emission standards requires consideration of wastes to be disposed, incinerator type and lifespan, waste segregation, existing controls and upgrading feasibility, performance indicators, ability to fine tune operating control parameters, cost, and available operating and performance skills.[16] Numerous facilities have established that properly designed, controlled and operated incinerator systems are environmentally safe and pose insignificant societal risks.[18] Finding a toxic contaminant in a hospital waste incinerator stack does not mean the concentration is harmful to the environment or public welfare. Contaminant concentration should be measured and applicable federal, state and local emission regulations should be consulted.

Incineration Advantages

Virtually all U.S. states either require or recommend incineration as the preferred hospital infectious waste treatment method.[18] Almost half the states and several major cities currently mandate on-site

infectious waste treatment, restrict off-site transport and/or prohibit infectious waste landfill disposal.[18]

Incineration not only sterilizes pathogenic waste but also reduces typical waste volume 80% to 95% and waste weight 50% to 80%.[15,18,41,53,67] These weight and volume reductions mean less disposal land is required and hauling costs and risks are decreased. High temperature incineration provides the safest, most reliable, cost-effective, and cleanest method for hospital infectious or biological waste disposal.[18,34] Total waste load incineration removes the need for costly, potentially dangerous, and time consuming waste segregation.[2]

Regulations

Incinerator use requires a permit from state or federal air pollution control agencies. State and local air emission requirements may require additional air pollution control equipment, such as bag houses and wet scrubbers.[67]

The federal government has responded to the hazardous/infectious waste problem by enacting several regulations: the Resource Conservation and Recovery Act (RCRA) in 1976 (Public Law 94-580), the Toxic Substance Control Act (TSCA) in 1976 (Public Law 94-469), and the Comprehensive Environmental Response Compensation and

Liability Act (CER-CLA) in 1980 (Public Law 96-510).[46] These regulations govern hospital infectious waste treatment and disposal. A hospital can be found liable for improperly disposed waste even when the hospital is unaware of the illegal activity. Liability under the federal Comprehensive Environmental Response, Compensation and Liability Act (more commonly known as "Superfund") is strict, joint, and several - anyone connected with the disposed waste may be held liable, including all institutions having contributed waste to a site, all transporters and disposal company owners or operators, any person who arranged disposal or transportation, and any past or present disposal site owners. The act is retroactive and without limit.[67]

Most recently the U.S. Congress approved the 1988 Medical Waste Tracking Act.[25] The medical and infectious waste disposal problem is one more of public perception than of public health concern but legislators recognized that the public often ignores "technical distinctions" and demands "special handling" of such material.[14,25] Widespread concerns about improperly disposed medical wastes provided the impetus for the quick action.

The legislation requires the EPA to establish a model medical tracking system in New York, New Jersey,

and eight midwestern states surrounding the Great Lakes.[25] Similar state legislation requires hospitals to keep records of infectious waste transported off-site and would hold hospitals liable if the regulations are violated, even if done so by private contractor. A New York state regulation will require a manifest and labeling system, and will implement a 1987 law requiring infectious waste high temperature incineration or steam sterilization.[34] The 1987 law also established a uniform infectious waste definition, and requires infectious material color-coding and licensed infectious waste hauler use.[34]

Recommended documentation to have available for facility safety committee and regulatory agency review include: policies and procedures manuals, an inventory and tracking of hazardous materials and waste program, permits, manifests, other material handling documents, and hazard surveys and similar types of inspection reports which are conducted as part of the safety committee's surveys.[47]

SUMMARY

Infectious hospital wastes can be decontaminated by either steam sterilization (autoclaving) or incineration. Autoclaving can be an effective waste treatment method if wastes are properly packaged and thoroughly sterilized. The high temperature steam needs to maintain the entire waste load temperature at $115^{\circ}C$ for a minimum 20 minutes. Often the hot steam does not totally penetrate the waste and the materials remain contaminated.

Incineration is the preferred infectious waste treatment method. Incineration more effectively destroys pathogens and reduces waste volume and weight. Incinerator temperatures must reach 1,800 to $2{,}000^{\circ}F$ for five seconds to sterilize infectious waste. Incineration requires highly trained personnel and well designed equipment. Air in-flow and waste feed rates are difficult to coordinate to maximize treatment efficiency and minimize contaminated air emissions. A dual chamber incinerator with air pollution control devices provides adequate material destruction and will properly control emissions. Hospital administrators must stay abreast of legislation and regulations, personnel training, incinerator operating procedures, equipment service and maintenance, operation hours, ash residue quality, air

emissions, and other related aspects.[43] Properly treated infectious hospital waste can then be safely landfilled.

CHAPTER 5: CONCLUDING REMARKS

Safe and effective hospital infectious waste disposal is accomplished by a well designed and operated waste control system. The proper disposal of potentially infectious wastes benefits hospital staff, patients, guests, and the surrounding community. This paper examined the necessary waste control system components to adequately address these needs. The paper paralleled a waste control system from the waste's generation to disposal.

A hospital waste disposal system is a primary way of controlling unintentional exposure to potentially infectious agents. Although no epidemiological evidence exists to suggest hospital waste is more harmful than residential waste, a hospital's societal position as a health care provider requires proper infectious waste control system design, implementation and operation.

U.S. hospitals generate an estimated 1.4 million pounds of infectious waste per day nationwide. Infectious waste disposal costs may approach $466 million per year. Hospital infectious waste disposal is definitely an area deserving attention and study.

A hospital infectious waste disposal system needs to address all functions necessary to remove and appropriately treat hospital waste. Proper infectious waste disposal is dependent upon the successful

integration of the waste control system components. Thorough employee training is a necessary part of any waste control system. Properly trained and supervised employees will reduce errors, protect employees, patients and equipment, and ultimately determine the waste disposal system's success or failure.

Waste collection and segregation were the first system components receiving attention. Waste needs to be collected and segregated at the generation point to reduce future material handling and ensure proper containment. Initial waste segregation minimizes the waste volume requiring specialized decontamination treatment. Proper collection and segregation requires employee training in correct waste handling procedures. Wastes should first be segregated infectious or non-infectious wastes and then be segregated according to the designated waste treatment method. The second segregation is necessary because some wastes can be effectively treated using steam sterilization but is only necessary if more than one infectious waste treatment method is practiced.

Segregated waste is then placed in proper containment packaging. The packaging material chosen can have a great effect on the disposal system's ability to adequately sterilize the waste load. Autoclaving requires packaging which is air and steam permeable.

Low-density polyethylene containment bags are recommended for steam sterilization. Incineration bound wastes should be packaged in combustible materials to provide additional primary chamber fuel and to eliminate potential container contamination.

Infectious waste transport requires closed containers to reduce inadvertent waste exposure or intermixing, and to improve esthetics. Desirable transport cart features and employee training materials were discussed in Chapter 3. Proper infectious waste transport routes and procedures minimize hospital population exposure to potentially infectious agents.

Infectious waste storage should be minimized. Destroying potentially infectious material quickly decreases contamination risks, and reduces storage space needed. Any infectious materials stored should be properly contained until disposal.

Steam sterilizing is an effective decontaminating treatment when appropriate wastes are properly packaged and the autoclaving process is correctly implemented. Effectively penetrating the entire load with high temperature steam may be difficult and is a major drawback to this sterilizing method.

High temperature incineration is the recommended infectious waste treatment technique. Incineration

effectively destroys pathogens, reduces the waste weight and volume and is cost-effective. Incinerating hospital wastes can produce undesirable incinerator emissions or contaminated ash. Reducing emissions can be accomplished through carefully controlling incinerator temperatures and residence times and installing air pollution control equipment. Contaminated ash may require chemical treatment before landfill disposing or increased incinerator temperatures. The incinerator's end product is then safe for sanitary landfill disposal.

Hospital administrators must actively participate in designing and supporting the infectious waste disposal system. The opportunities for mishandling wastes and creating potentially dangerous situations exist and must be controlled. A properly designed and operated waste disposal system provides hospital staff and patient safety, and produces a by-product which is environmentally safe. Incinerating a hospital's infectious wastes eliminates potentially contaminating materials from the community.

Hospitals are recognized as health providers and health protectors. As such, hospitals have the responsibility of effectively and efficiently controlling the infectious wastes generated. The means of attaining this important goal is a properly designed, implemented and operated infectious waste disposal system.

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APPENDIX A

TABLE 1.0 CDC, JCAH, and EPA Recommended Infectious Waste Disposal Methods

Solid Waste	CDC	JCAH	EPA
Microbiological	S,I	S,I	S
Blood & Blood Products	S,I Sew (blood)	SL,Sew	S,I
Communicable Disease Isolation	S,I	SL,Sew	S,I
Pathological	I	I	I,SW,CB
Items Containing Secretions, Excretions	N	SL,Sew	-
Contaminated Lab Waste	-	S,I	S,I
Surgical, dialysis unit	-	-	S,I

Abbreviations: S-steam sterilization, I-incineration, SL-sanitary landfill, Sew-sewage after grinding when appropriate, SW-steam sterilization with incineration or grinding, CB-cremation or burial by mortician.

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TABLE 2.0 1985 JCAH STANDARD VI for Hazardous Materials and Waste

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Standard VI

There is a system that is designed to safely manage hazardous materials and wastes.

Required Characteristics:

A. The system addresses the management of hazardous materials and wastes from the point they enter the hospital to the point of final disposal.

B. The system addresses the protection of patients, personnel, visitors, and the community environment.

C. Policies and procedures are developed that include a process for identifying hazardous materials and wastes (e.g. toxic materials, infectious wastes, radioactive materials) and for managing them using techniques such as substitution of less hazardous agents, changes of processes, isolation, and ventilation.

D. Policies and procedures relating to the operation of the system are reviewed at least annually to the safety committee for chemical and physical hazards, by the infection control committee for infectious hazards, and by the radiation committee for radioactive hazards. Recommedations, conclusions, and actions of these committees are reported to the hospitalwide quality assurance function.

E. Individuals required to handle hazardous materials or wastes are provided with appropriate job training.

F. The system includes a program for controlling the handling and disposal of gaseous hazardous materials. Included in this program are procedures pertaining to the control of waaste gas levels in areas such as surgical suites, central supply, and laboratories.

G. The system includes a program for controlling the handling and disposal of liquid and solid hazardous materials. Included in this program are procedures pertaining to the elimination of hazards by: elimination and treatment of wastes at the source; packaging of the wastes; safe transport systems within the hospital; and adequate and safe disposal facilities either on or off-site.

H. The system is established and operated in accordance with federal, state and local regulations. Compliance with JCAH standard does not relieve the facility of the responsibility to comply with other applicable federal, state and local codes.

I. All components of the waste management system, including transport systems, storage areas, and treatment facilities, are subject to safe and sanitary practices. Such practices include prevention of contamination of patient care, food preparation, and serving areas by waste compaction and storage areas.

From "Functional Safety and Sanitation," Accreditation Manual for Hospitals (Joint Commission on Accreditation of Hospitals, 1985), 132-133.

TABLE 3.0 STATES HAVING INFECTIOUS WASTE REGULATIONS

State	Regulations Issued	Guidelines Issued	Legal Definitions
Alabama	X		
Arizona		X	
Arkansas	X		X
California	X		X
Colorado	X		
District of Columbia	X		X
Florida	X		X
Georgia	X		X
Hawaii	X		X
Idaho	X		X
Illinois	X		X
Indiana	X		X
Iowa	X		
Kansas	X		X
Kentucky	X		X
Louisiana	X		X
Maryland	X		X
Massachusetts			X
Minnesota	X		X
Missouri	X		
Nebraska	X		X
Nevada	X		X
New Hampshire	X		X
New Jersey	X		X
New York	X		X
North Carolina	X		X
North Dakota	X		X
Oregon	X		
Pennsylvania		X	X
Rhode Island	X		X
South Carolina		X	
Tennessee	X		X
Texas	X		X
Utah	X		X
Vermont	X		X
Virginia		X	
West Virginia		X	

From Hospitals 62 (1), January 5, 1988: 97.

APPENDIX B

TABLE 1.0 INFECTIOUS WASTES

Types of Infectious Waste	Examples	Possible Sources/Departments
Isolation wastes	Linens, soiled dressings, sponges, paper goods containing body fluids, leftover food, disposable masks	From rooms used to house patients with dangerous communicable diseases
Contaminated lab wastes	Lab dishes, anything that may have come into contact with pathogens, paper or cloth, pipettes, filters, syringes, swabs, slides	Research and test laboratories, pathology, morgue
Clinical specimens	Specimens kept for research and then discarded	Laboratories, autopsy rooms, morgue
Blood and blood products	Blood samples taken for testing all items contaminated with blood	Labs, blood banks, dialysis rooms, pharmacy, patient rooms
Surgery and autopsy wastes	Soiled dressings, sponges, syringes, masks, gloves, underpads, tests catheters, body tissue. Everything in contact with body fluids and blood	Surgery areas and autopsy rooms
Dialysis wastes	Disposal dialysis equipment (tubes and filters), linens, gloves, lab coats, aprons, masks	Dialysis unit
Discarded biologicals	Vaccines no longer usable or needed	Pharmacy, labs
Sharps	Needles, syringes, pipettes, broken glass, scalpel blades	Patient rooms, surgery, emergency rooms, nurses station, labs, morgue, pathology
Pathological waste	Body tissue, organs, blood and removed body fluids, body parts	Operating rooms, labs, autopsy room, operating rooms, pathology department
Contaminated equipment	Equipment and parts used in treatment and testing, HEPA filters	Labs, surgery, patient rooms
Wastes from stocks of etiologic agents	Specimens, cultures	Pathological labs, medical labs, pharmacy, research labs
Animal carcasses and body parts	Includes carcasses and body parts of all animals used in production of biologicals and pathogen testing	Research labs
Animal bedding & other animal room waste	All bedding and animal secretions and excretions from diseased and research animals	Research labs
Wastes from multiple hazards	Physically harmful wastes and chemical wastes exposed to pathogens	Throughout the hospital

From Draft Manual for Infectious Waste Management (SW-957), (Washington, D.C.: Environmental Protection Agency, 1982).

TABLE 2.0 HOSPITAL WASTE GENERATED PER PATIENT BY HOSPITAL SIZE (licensed beds)

Hospital Beds	Number of Hospitals	lb./bed/day	lb./patient/day
<100	14	9.03	11.85
100-299	21	9.75	12.79
300-499	9	10.76	14.12
>500	6	11.55	16.16
Mean		9.95	13.06

From Rutala, William A., and Felix A. Sarubbi, Jr., "Management of Infectious Waste from Hospitals," Infection Control 4 (4), 1983: 199.

APPENDIX C

TABLE 1.0 Large Hospital Disposal Costs

Category	Cost Range
Hauling Infectious Waste	$.15-.25/lb. ($9-$11/yard)
Hauling General Waste	$1.60-$5.40/yard (compacted)
Infectious Waste Incineration	$.12-.25/lb.

National average infectious waste hauling cost is approximately $.40/lb.

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HOSPITAL INFECTIOUS WASTE DISPOSAL SYSTEM DESIGN

by

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AN ABSTRACT OF A REPORT

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ABSTRACT

This document addresses hospital infectious waste disposal system design. The paper's goal is to provide information regarding the treatment of infectious hospital waste from the generation point to ultimate disposal.

Chapter 1 provides the reader an introduction and methodology. Chapter 2 investigates infectious waste regulation, composition, generation, and disposal costs. Additionally Chapter 2 questions whether infectious hospital wastes are any more harmful than municipal wastes. Chapter 3 discusses waste handling regulations, collection, segregation, containment, transportation, and storage. Waste handling employee training program subjects are then outlined. Chapter 4 provides an examination of the two most popular waste treatment alternatives: steam sterilization and incineration. Factors important to system design are discussed for both these infectious waste treatment methods. Chapter 5 provides concluding remarks to the paper.

Infectious hospital waste should be segregated at the generation point by trained waste handlers. Waste determined infectious should be properly contained in materials congruent to the designated waste treatment method. All waste transport should be in approved waste

containers which provide the utmost hospital staff, patient and visitor protection. Incineration is the recommended waste treatment alternative. Incineration effectively controls pathogens, reduces waste volume and weight, and is cost-effective. Proper incineration is a difficult process to control; air emissions and residue ash require monitoring to ensure safety and adherence to applicable statutes.